AD-A016 135

TWO PROGNOSTIC INDICES FOR THE TRAUMA PATIENT

W. J. Sacco, et al

Edgewood Arsenal
Aberdeen Proving Ground, Maryland

August 1975

303103

AD

EDGEWOOD ARSENAL TECHNICAL REPORT

EB-TR-75066

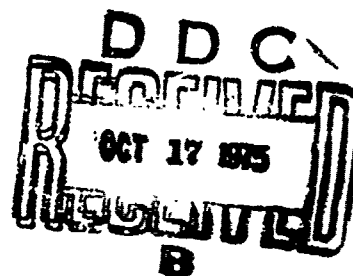# TWO PROGNOSTIC INDICES FOR THE TRAUMA PATIENT

by

William J. Sacco, Ph.D.
Michael A. Goldfarb, M.D., MAJ, MC
Michael W. Weinxtein, M.D., MAJ, MC
Terrence F. Ciuraj, M.D., CPT, MC

Biomedical Laboratory, Edgewood Arsenal

R. A. Cowley, M.D.
H. R. Champion, F.R.C.S. (Ed.)
W. Gill, F.R.C.S. (Ed.)
W. B. Long, M.D.
T. C. McAdan, M.B.

Maryland Institute for Emergency Medicine
Baltimore, Maryland

August 1975

D D C

OCT 17 1975

B

Approved for public release; distribution unlimited.

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER EB-TR-75085	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TWO PROGNOSTIC INDICES FOR THE TRAUMA PATIENT	5. TYPE OF REPORT & PERIOD COVERED Technical Report April 1974– March 1975	
	6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s) W. J. Sacco T. F. Ciurej W. Gill M. A. Goldfarb R. A. Cowley W. B. Long M. A. Weinstein H. R. Champion T. C. McAslan	8. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Commander, Edgewood Arsenal Attn: SAREA-BL-BS Aberdeen Proving Ground, Maryland 21010	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS EA Project 3A162110A821 AMSAA Project DAA D0573C003.	
11. CONTROLLING OFFICE NAME AND ADDRESS Commander, Edgewood Arsenal Attn: SAREA-TS-R Aberdeen Proving Ground, Maryland 21010	12. REPORT DATE August 1975	
	13. NUMBER OF PAGES 12	
14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE NA	

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Evaluation of the care of the critically ill patient

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Trauma indices
Probabilities of survival
Tracking patients
Respiratory index nomogram
Prognosis regions

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

    A trauma index, called the CHOP index, based on serum creatinine, hematocrit, serum osmolality, and systolic blood pressure was evolved from retrospective and prospective studies of 700 patients from the Maryland Institute for Emergency Medicine. A decision rule which predicts death or survival resulted in a misclassification rate of less than 10% for patients in the trauma unit for more than 1 day.

(Continued on reverse side)

29. ABSTRACT (Contd)

The CHOP index and a respiratory index were utilized in a retrospective study of 177 consecutive intubated patients. Prognosis regions were specified in the *space* determined by the two indices. A nomogram which allows one to follow the course of a patient with respiratory problems is described.

These results have been applied to animal-human blunt trauma ballistics studies. Valuable as the results are for animal-human correlation studies, we believe they are dwarfed by the applications to military and civilian medicine including trauma patient prognosis and monitoring, triage of mass casualties, objective method of evaluating care of critically ill patients, and comparison of therapeutic regimens.

PREFACE

The work described in this report was authorized under Project 3A162110A821, Evaluation of the Care of the Critically Ill Patient; and AMSAA contract DAA D0573C0032. This work was started in April 1974 and completed in March 1975.

CONTENTS

TWO PROGNOSTIC INDICES FOR THE TRAUMA PATIENT

I. INTRODUCTION.

Attempts to produce an objective assessment of the severity of illness of a patient are important for epidemiologic studies; to compare incidence, management, and therapeutic results from center to center; and to produce a more accurate prognosis for individual patients.

A number of pattern recognition techniques have been used by members of the Shock Trauma Branch of the Biophysics Division, Edgewood Arsenal, Maryland; US Army Materiel Systems Analysis Activity (AMSAA), Aberdeen Proving Ground, Maryland; and the Maryland Institute for Emergency Medicine (MIEM), Baltimore, Maryland, to determine compact physiological and biochemical indices which quantitatively characterized post-traumatic states. These indices frequently characterize the patient more accurately than do the physicians.

In this paper we report on two indices. A trauma index (called the CHOP index) based on serum creatinine, hematocrit, serum osmolality, and systolic blood pressure evolved from a retrospective and then a prospective analysis of over 700 patients from the MIEM.[1] A decision rule which predicts death or survival resulted in a misclassification rate of less than 10% for patients in the trauma unit for more than 1 day. A respiratory index, which is the alveolar-arterial oxygen difference divided by the arterial partial pressure of oxygen, was investigated in a retrospective study of 177 consecutive intubated patients treated at the MIEM. A respiratory index of 0.1 to 0.37 is normal. All patients with a respiratory index of 2 or greater were intubated. Patients with a respiratory index over 6 had a 12% chance of survival.[2] Prognosis regions are specified in the space determined by the two indices. A nomogram which allows one to follow the course of a patient with respiratory problems is described.

II. BACKGROUND.

The study of shock and trauma has applications to both the civilian and military communities. One of the foremost is to gain knowledge leading to improved therapy for severely injured patients. In studies of World War II, Korea, and Vietnam casualty data, it has been found that shock and/or hemorrhage was the primary cause of death in 36% to 68% of all battle fatalities. The recent establishment of the William Beaumont Hospital, Fort Bliss, Texas, also indicates the Army's commitment to the study of shock and trauma.

The organization of shock-trauma centers such as the MIEM reflects the civilian need to treat severely injured patients. At the present time the MIEM treats over 700 patients each year. Similar units are being established throughout the country.

A systems study of the effects of shock and trauma on humans was undertaken in September 1971 jointly by the Biophysics Division, the AMSAA, and the MIEM. The MIEM data bank contains clinical, cardiovascular, metabolic, and therapeutic information on more than 2000 patients. The data bank has been duplicated at the Biophysics Division, and an extensive computer retrieval program has been written to give easy access to the data.

The initial objectives of the study were (1) to specify *profiles* of physiological and biochemical measurements which would reflect the severity of illness of a patient, (2) to delineate good and poor *prognosis regions* in the *profile space*, and (3) to describe and evaluate the change in patient's state with time.

A pattern analysis was conducted on an existing data set consisting of first day values and final values on day of death or discharge from the unit. A subset of 12 parameters appeared to have the highest predictive value for mortality. Probabilities of survival and death were computed for regions of the 12-dimensional *profile space*.[3]

With the completion of the computer retrieval program, data from many time periods became available for each patient. The course of each patient is then characterized by a set of variables (profile) whose values may change rapidly with time as the patient's condition improves or deteriorates. In attempting to discriminate survivors

from nonsurvivors, we were confronted with a *nonstationary* discrimination problem. In mathematical terms this means that the probability density functions which characterize the survivors and nonsurvivors are time varying because they depend on the patient's changing condition. At this time we chose to characterize patients by the notion of derangement or *distance from normality*, which traditionally has been a qualitative guide for clinicians.

On the basis of the previous study and clinical judgment, serum creatinine (C), hematocrit (H), serum osmolality (O), and systolic blood pressure (P) were selected to form a set of parameters called CHOP. A CHOP index was devised based on the four variables. It is the square root of the sum of the squares of the deviations (measured in standard deviation units) from *normal* average values of the four variables; that is,

$$\text{CHOP index} = \sqrt{\left(\frac{C-1.0}{0.5}\right)^2 + \left(\frac{H-37.0}{6.0}\right)^2 + \left(\frac{O-292.0}{15.0}\right)^2 + \left(\frac{P-127.0}{21.0}\right)^2}$$

In mathematics, this quantity is called the *Euclidean distance* and reflects the difference between an *actual* patient's state and a *desired* patient's state. In each of the squared terms in the sum under the radical, the number in the numerator is the estimated normal average value of the variable, and the number in the denominator is the estimated standard deviation of that variable. For example, 37.0 is the average for hematocrit (H) and 6.0 is the standard deviation. These estimates of the averages and standard deviations were obtained from final recorded values from 350 survivors.

A retrospective study of 100 patients and a prospective study of 600 patients indicated that a total distance (of CHOP index) over five units was associated with a poor prognosis.[1] A decision rule which predicts death or survival resulted in a misclassification rate of less than 10% for patients in the trauma unit for more than 1 day. Also in the prospective study, clinical prognoses were matched with the calculated daily distance. In over half the cases that went on to die, a distance of 5 was reached before the clinician thought that the patient was critical—no less terminal.

Two limitations of this CHOP index became evident. First, there were cases of isolated respiratory failure or central nervous system damage that were not always "reflected" by the four parameters. These patients might, therefore, die never having reached a distance of 5. To refine this index further, with regard to patients with central nervous system damage, an index incorporating level of consciousness, serium sodium, arterial pH, and intracranial pressure has been developed by J. E. Dunn and W. J. Sacco, but this will not be detailed here.[4]

To "capture" those patients with respiratory failure, a *respiratory* index, orignially suggested by Siegel,[5] was tested.[2] The index is the alveolar-arterial oxygen difference, divided by the arterial PaO_2

$$\frac{\left[(P_B - P_{H_2O}T)\,FIO_2 - PaCO_2\right] - PaO_2}{PaO_2} = \frac{P(AaDO_2)}{PaO_2}$$

where

P_B = barometric pressure

$P_{H_2O}T$ = alveolar water vapor pressure at the patient's temperature (T) (approximately 47 mm Hg)

$PaCO_2$ = arterial partial pressure of carbon dioxide assumed to be equal to the alveolar partial pressure of the carbon dioxide ($PaCO_2$)

FIO_2 = fractional concentration of O_2 in inspired gas.

The $P(AaDO_2)$ is divided by the PaO_2 since a particular $P(AaDO_2)$ could be the same value in two quite different clinical situations. For example, a patient on 70% FIO_2 with a PaO_2 of 70 would have a $P(AaDO_2)$ of about 400 and so would a patient on 90% with a PaO_2 of 200. By dividing the $P(AaDO_2)$ by the PaO_2, however, the index is 5.8 and 2, respectively. The respiratory index then more accurately reflects the clinical situation.

The numerator of the index reflects pulmonary shunting commonly caused by atelectasis, pulmonary contusion, or pulmonary embolism. In a retrospective study, the index was calculated in 177 patients wno were admitted between March 1971 and August 1972 to the MIEM. About 32% of the patients were transferred from other area hospitals at least 1 day after treatment was initiated. The others were usually brought to the hospital 30 to 45 minutes after injury by helicopter or were transferred to the unit from another hospital on the day of injury. The 177 cases represent consecutive intubated patients in the unit more than 1 day. The respiratory index was calculated each time therapy was changed or at least four times a day for as long as the patient was intubated or trached. A nomogram (figure 1) was designed for easy determination of the respiratory index assuming that the pCO_2 remains around 35 mm Hg. The FIO_2 measurement noted while the patient was on the Engstrom respirator had a standard deviation of ±5%. The nomograms are also used to:

1.   Graphically represent a patient's respiratory progress or deterioration.

2.   Predict changes in PaO_2 following changes in the FIO_2.

3.   Indicate any benefit from positive end expiratory pressure or from other treatment.
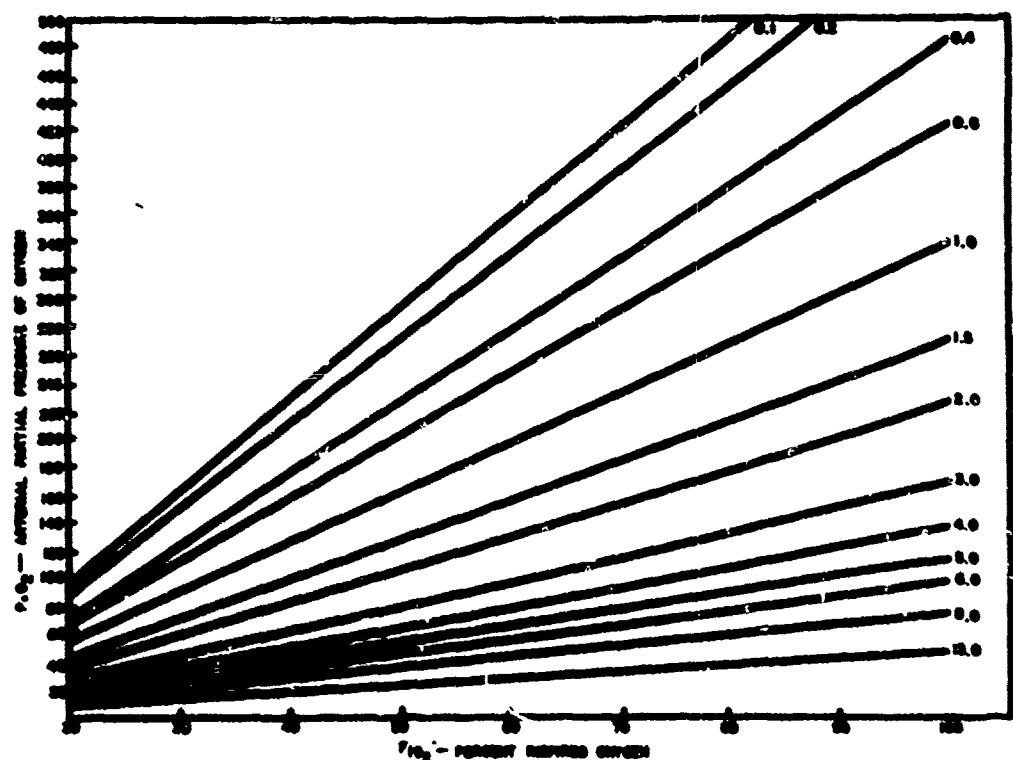

Figure 1.   Respiratory Index Nomogram

7

The respiratory index appears valid for a wide range of lung pathology involving shunting. As long as the patient remains on an isobar, changes in FIO_2 will register changes in PaO_2 predicted by the graph. If the patient does not remain on the same isobar after suctioning or increase in FIO_2, then a change to a lower respiratory index isobar would indicate improvement in his condition. A change to a higher respiratory index isobar would indicate deterioration in the patient's stature.

In summary, the results indicate that all patients with a respiratory index of 2 or more were intubated. A patient with a respiratory index over 6 had a 12% chance of survival.

The predictive value of the CHOP index was then combined with the respiratory index (figure 2). One hundred and seventy-two cases were studied. This was the same group tested with the respiratory index except for five patients that had incomplete data sets so that a CHOP index was not calculated. Of the 172 cases, 59 (34%) died, and 113 (66%) lived. In box I, however, note that if a patient had a CHOP index no higher than 5 and a respiratory index under 6, he had a 90% chance of survival (P_s) instead of 66% for an information gain of 24%. Most of the deaths in this group represent patients who had isolated CNS damage. In box II, if a patient had a CHOP index over 5 and a respiratory index under 6, he had a 28% chance of survival (an information gain of 38%).

	CHOP INDEX	
	<5	<5
RESPIRATORY INDEX >6	III P_s = 10% 9 – D 1 – L	IV P_s = 6% 17 – D 1 – L
RESPIRATORY INDEX <6	I P_2 = 90% 11 – D 103 – L	II P_s = 28% 22 – D 8 – L

Figure 2.   Respiratory Index and CHOP Index Combined

Those that survived here represent therapeutic triumphs in severely ill patients. In box III, a respiratory index over 6 and a CHOP index under 5 was associated with a 10% survival (an information gain of 56%). In box IV, representing the most seriously ill patients, a respiratory index over 6 and a CHOP index over 5 was associated with a 6% chance of survival (an information gain of 60%).

III.   CLINICAL APPLICATIONS.

In this paper we have reported the application of some pattern recognition techniques to the study of human trauma. There is no generally accepted codified measure of patient's illness. We believe it is now possible to

specify with confidence the prognosis following serious injuries based on quantitative expressions involving physiological and biochemical parameters. These results have been applied to animal-human blunt trauma studies.[6] Valuable as the results are for animal-human correlation studies, we believe they are dwarfed in importance by the applications to military and civilian medicine. The applications to the medical community are the following:

1. Objective method for the *evaluation of intensive care units*: For example, suppose that of 100 consecutive patients, unit A has 10 cases with the CHOP index over 5 and saves 10%, whereas unit B has 50 with a CHOP index over 5 and saves 30%. Unit A then handles fewer critically ill patients and also has worse results. This approach is currently being considered by the Surgeon General.

2. Different *therapeutic regimens* may be compared in patients who have similar states, say, a set of patients, all of whom have an index of 5.

3. With regard to *both the CHOP index* and the respiratory index, *trends* appear and alert the physician before the patient is clinically severely ill.

4. With regard to *patient monitoring*, another series of parameters such as pulse, urine output, systolic blood pressure, and CVP may be combined. If their total distance from normality is small, then the values of each parameter must be normal. A one-line oscilliscope readout could, therefore, substitute for individual measurements.

5. Patients with *disease states other than trauma* may be similarly evaluated.

6. A *"test tube triage"* system for large numbers of casualties is being researched. The object would be to match the scenario with available medical facilities with regard to military and civilian circumstances.

Several final points will be stressed. The indices are composed of measurements obtained in most centers. They are simple to obtain by hand, nomogram, or table look-up. Their reliability is enhanced by their *inherent irreversibility*. For once a patient has a CHOP index over 5 or a respiratory index over 6 and then proceeds to decrease in one or both categories he still appears to have the same poor prognosis. Any new set of proposed parameters can easily be tested by information gain techniques to determine its predictive power. More specifically, a measure of information inherent in an index is called the "information gain." It has the following interpretation. Suppose an intensive care unit manages to save 80% of its patients; the probability of survival, P_L, of an arriving patient is, therefore, 0.8. If the physician is given additional information about a particular patient, he might be able to alter the prognosis from 0.8 to 0.2. The gain in information would be the absolute difference in the prognoses. Here the information gain would be $.8 - .2 = .6$. If we let x designate the index to be evaluated, then the average information gain, I, is

$$I = \sum_{i=1}^{n} |P_L - P(L|x \text{ is in bin } i)| \, [\text{probability that } x \text{ is in bin } i]$$

where

$$P_L = \text{the prior probability that a patient will live}$$

and

$$P(L|x \text{ is in bin } i) = \text{the conditional probability that a patient will live} \\ \text{given that index x belongs to bin i.}$$

The information gain may also be used to test any other parameter which one may want to include to enhance the validity of a prognosis. The information gain analysis would indicate the value of the new parameter.

In conclusion, an index is merely a number which may be related to a probability of survival in a group of trauma patients. It is not a death sentence; it is only a measure of a sick patient's ability to override a major illness compared to other patients. Its final purpose "at the bedside" is not to replace the traditional precepts of history and physical examinations, but rather to give additional information which the physician may use in patient management.

LITERATURE CITED

1. Sacco, W., Cowley, R., Goldfarb, M., Champion, H., Gill, W., Long, W., and Copes, W. Application of Pattern Recognition to Trauma Studies, Proceedings of the First International Joint Conference on Pattern Recognition. Washington, D.C. 1973.

2. Goldfarb, M., Ciurej, T., Sacco, W., and Weinstein, M. EB-TR-73061. A Simple Respiratory Guide for Respiratory Therapy in the Trauma Patient. January 1974. UNCLASSIFIED Report.

3. Copes, W., Cowley, R., Masastis, C., Sacco, W., Sperrazza, J., and Turney, S. Application of Pattern Recognition to Shock-Trauma Studies, Proceedings of Computer Graphics in Medicine. Pittsburgh, Pennsylvania. 1972.

4. Dunn, J., Sacco, W., and Broome, P. A Multidimensional Statistical Analysis of 321 Consecutive Patients with Central Nervous System Injury. Congress of Neurological Surgeons, Hawaii. 1973.

5. Siegel, J., and Farrell, E. A Computer Simulation Model to Study the Clinical Observability of Ventilation and Perfusion Abnormalities in Human Shock States. Surgery 73, No. 6., 898-1912 (1973).

6. Montanarelli, N., Hawkins, C., Goldfarb, M., and Ciurej, T. Protective Garments for Public Officials, Land Warfare Laboratory Technical Report, No. LWL-TR-30B73. 1973.